Appendixes

A. **Design Flows for Performance Tests**

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Appendix A: Design Flows for Performance Tests

DETERMINATION OF BENCH-TEST FLOW RATES

The flow rate for each of several different sets of assumptions was calculated as presented below. The "pros" and "cons" of each set of assumptions was considered. The assumed tributary area to the catch basin is 10,000 ft2 (about 4 catch basins per acre)
Use the mean rainfall intensity: Reflects the understanding that 60% of rainfall falls at an intensity less than 0.1 in/hour; loosely defined as the "mean intensity".

Flow: 10.4 GPM

(1) Most representative of the area's rainfall rates
(2) Low flow eases the logistics of the bench testing

Use the peak period of the annual mean storm: Use the peak 20 minute period of the mean storm (0.50 inches in 24 hours) assuming a pattern of the SCS Type IA storm. With this assumption, 18% of the rainfall occurs in the peak 20 minute period.

28 GPM

(1) Represents the extreme period of the average condition.

(1) Increases logistics requirements of the bench test.
(2) Not representative of anything in particular.

Use a flow rate representative of research on other BMPs: Use a flow rate that is similar to those observed in the research of other Treatment BMPs. Storm depths examined in the grass swale work at Mountlake Terrace varied from 0.17 to 1.25 inches over a duration range of 3 to 11.5 hours, for a range of average intensity per storm of 0.04 to 0.20 inches per hour. Given that the test area was only about 44% impervious, this translates to a storm depth of about 0.02 to 0.09 inches per hour, or a runoff rate of about 2 to 9 gpm for a 10,000 ft2 catchment.

Flow: 5 to 10 gpm

(1) Allows comparison of performance to grass swale research.
(2) Low flow eases the logistics of the bench testing

Use average flow rate of the 6-month storm: Storm depth of 0.65 inches over 24 hours, or an average intensity of 0.027 inches per hour.

Flow: 2.8 gpm

(1) Represents the DOE design storm
(2) Low flow eases the logistics of the bench testing

Use the peak of the 6-month storm: Using Rational Method; Q = CIA with C = 0.9, I = 0.60 inches/hour and A = 0.25 acres.

Flow: 61 GPM

(1) Represents the extreme period of the DOE design storm. Therefore, if the inserts can perform at this rate, they are able to perform throughout the DOE design storm.

(1) Increases logistics requirements of the bench test.

Summation: Selecting a flow between 5 and 10 gpm seems the most appropriate. It reasonable represents the average condition, and is similar to flow rate of on other local research project. This range lies between the average and peak of the 6-month storm.

DETERMINATION OF FLOW RATE FOR THE TREATMENT AREA TEST

Use the peak of the 6-month storm: Using Rational Method; Q = CIA with C = 0.9, I = 0.60 inches/hour and A = 0.25 acres.

Flow: 61 GPM

DETERMINATION OF FLOW RATE FOR THE OVERFLOW CAPACITY TEST

Consideration of grate capacity:

- Using 18" by 24" catch basin
- Grate consists of 16 slots (two parallel rows, 8 each)
- Each slot ¾" by 9 ½"
- ¼ acre catchment

$Q = 3PD^{1.5}$
D = depth of water over the grate
P = grate perimeter

Using a depth of 0.1 feet

$Q = 3x(4x9.5+16x0.75)(0.1)^{1.5}/12$
$Q = 0.4$ cfs = 177 gpm

Using a depth of 0.4 feet

$Q = 3.16$ cfs = 1,418 gpm

Consideration of outlet capacity:

- 8" outlet
- 0.5% slope
- no surcharge

From pipe diagram, the capacity is about 300 gpm.
Summation: Use the flow rate that represents the capacity of the grate without flooding.

Appendix B: Water Quality Data from Bench Tests

Raw data from each of the bench tests are presented in the following pages. Analytical methods and reporting limits are provided in Tables 9.

Table 9. Analytical Methods and Detection Limits.

WATER

Parameter	Method	Units	Reporting Limit
Oil and Grease	413.2	mg/l	1.0
Total Suspended Solids	160.2	mg/l	5.0
Turbidity	180.1	NTU	1.0
Total & Dissolved Zinc	289.1	mg/l	.04
Total Lead	239.2	mg/l	.002
Total & Dissolved Copper	220.2	mg/l	.001
Total Phosphorus	ICP	mg/l	.05
Hardness	130.2	mg/l	1.0

SEDIMENT

Parameter	Method	Units	Reporting Limit
TPH	WTPH 418.1	mg/kg	
PAH	8310	mg/kg	
Total Metals		mg/kg dry	
As	7060		0.100
Cd	7130		0.005
Cr	7190		0.050
Cu	7210		0.050
Pb	7420		0.050
Ni	7520		0.050
Zn	7950		0.025

First Sequence Test Data

Enviro-Drain (ED-SAC) - Industrial Site

Parameter	Date	3/30/94						6/8/94						8/23/94			
	Session	0						1						2			
Units	Total Days	0						64						133			
MDL	Total Rain	0.00						2.45						3.86			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	100						56						82	85	81	81
(mg/L)	Outflow	104	140	85	96	98	99	57	50	60	62			80	81	68	90
5.0	Reduction	-4%						-2%						3%			
Turb.	Inflow	153						110						219			
(NTU)	Outflow	152						115						210			
	Reduction	1%						-5%						4%			
Tot P	Inflow	0.18						0.24									
(mg/L)	Outflow	0.27						0.21	0.24	0.19	0.21						
0.050	Reduction	-50%						11%									
O/G	Inflow							30	32	28				29	32	28	28
(mg/L)	Outflow	NT						26	27	25	25	28	23	26	24	28	27
1.0	Reduction							15%						10%			
Hard	Inflow																
(mg/L)	Outflow	420															
1.0	Reduction																
Tot Cu	Inflow	18						13									
(ug/L)	Outflow	12						13	12	13	13						
1.0	Reduction	33%						3%									
Tot Pb	Inflow	18						14									
(ug/L)	Outflow	15						15	16	14	14						
2.0	Reduction	17%						-5%									
Tot Zn	Inflow	180						170						110	110	110	110
(ug/L)	Outflow	162	170	170	150	140	180	180	180	180	180			263	320	240	230
20	Reduction	10%						-6%						-139%			
Dis Cu	Inflow	3															
(ug/L)	Outflow	2															
1.0	Reduction	0															
Dis Zn	Inflow	68															
(ug/L)	Outflow	54															
20	Reduction	21%															

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Aqua-Net (ANS) - Industrial Site

Parameter	Date	3/30/94						6/8/94						8/23/94			
	Session	0						1						2			
Units	Total Days	0						64						133			
MDL	Total Rain	0.00						2.45						3.86			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	99						52						80	81	68	90
(mg/L)	Outflow	94	93	98	98	94	86	73	66	76	78			98	94	100	100
5.0	Reduction	5%						-41%						23%			
Turb.	Inflow	145						110						219			
(NTU)	Outflow	149						126						238			
	Reduction	-3%						-15%						-9%			
Tot P	Inflow	0.19						0.26									
(mg/L)	Outflow	0.20						0.26	0.26	0.26	0.26						
0.050	Reduction	-5%						0%									
O/G	Inflow																
(mg/L)	Outflow	NT															
1.0	Reduction																
Hard	Inflow																
(mg/L)	Outflow	840															
1.0	Reduction																
Tot Cu	Inflow	12						13									
(ug/L)	Outflow	11						15	14	17	14						
1.0	Reduction	8%						-15%									
Tot Pb	Inflow	17						14									
(ug/L)	Outflow	11						17	16	18	17						
2.0	Reduction	35%						-21%									
Tot Zn	Inflow	190						160						130	140	130	120
(ug/L)	Outflow	182	200	180	170	180	180	190	180	200	190			700	1000	620	480
20	Reduction	4%						-19%						-438%			
Dis Cu	Inflow	1.9															
(ug/L)	Outflow	2.0															
1.0	Reduction	-5%															
Dis Zn	Inflow	44															
(ug/L)	Outflow	130															
20	Reduction	-195%															

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Stormwater Services (SS-1) Industrial

Parameter		3/30/94						6/8/94						8/23/94			
Units	Session	0						1						2			
MDL	Total Days	0						64						133			
	Total Rain	0.00						2.45						3.86			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	110						62						81	82	80	82
(mg/L)	Outflow	81	79	83	80	77	85	71	70	70	74			111	120	120	93
5.0	Reduction	27%						-15%						-36%			
Turb.	Inflow	103						112						216			
(NTU)	Outflow	96						123						228			
	Reduction	5%						-10%						-6%			
Tot P	Inflow	0.19						0.22									
(mg/L)	Outflow	0.15						0.25	0.23	0.25	0.27						
0.050	Reduction	21%						-14%									
O/G	Inflow													17	22	14	14
(mg/L)	Outflow	NT												16	19	15	13
1.0	Reduction													6%			
Hard	Inflow																
(mg/L)	Outflow	390															
1.0	Reduction																
Tot Cu	Inflow	17						13									
(ug/L)	Outflow	12						18	18	18	19						
1.0	Reduction	29%						-41%									
Tot Pb	Inflow	17						14									
(ug/L)	Outflow	12						42	42	37	47						
2.0	Reduction	29%						-200%									
Tot Zn	Inflow	190						183	170	190	190			127	130	130	120
(ug/L)	Outflow	138	120	140	140	160	130	297	300	290	300			857	700	900	970
20	Reduction	27%						-62%						-576%			
Dis Cu	Inflow	2.6															
(ug/L)	Outflow	1.8															
1.0	Reduction	31%															
Dis Zn	Inflow	110															
(ug/L)	Outflow	62															
20	Reduction	44%															

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Stormwater Services (SS-20) Park-and-Ride Site

Parameter	Date	3/30/94						05/26/94						6/21/94						8/16/94			
	Session	0						1						2						3			
Units	Total Days	0						56						83						140			
MDL	Total Rain	0.00						2.00						3.16						3.35			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	96						110						92	100	83				157	160	160	150
(mg/L)	Outflow	89	92	91	89	89	84	127	140	130	110			88	93	82	90	85		140	150	130	140
5.0	Reduction	7%						-15%						4%						11%			
Turb.	Inflow							231						85						245			
(NTU)	Outflow							230						83						224			
	Reduction							0%						2%						9%			
Tot P	Inflow	0.18												0.20									
(mg/L)	Outflow	0.15							0.50	0.49	0.37			0.21	0.20	0.22	0.20						
0.050	Reduction	17%												-5%									
O/G	Inflow	36	37	37	37	34		35	35	35	35			56	57	56	54			17	22	14	14
(mg/L)	Outflow	4.5	4.6	4.4	4.6	4.4		31	30	35	27			41	47	40	45	35	37	16	19	15	13
1.0	Reduction	88%						12%						27%						6%			
Hard	Inflow																						
(mg/L)	Outflow	450																					
1.0	Reduction																						
Tot Cu	Inflow	14						8						39									
(ug/L)	Outflow	13						14	7	18	18			25	21	20	33						
1.0	Reduction	7%												37%									
Tot Pb	Inflow	18						13						30									
(ug/L)	Outflow	13						18	10	21	22			26	26	25	27						
2.0	Reduction	28%												13%									
Tot Zn	Inflow	200						220						300						187	210	170	180
(ug/L)	Outflow	164	160	160	150	170	180	210	210	210	210			270	280	280	250			183	180	200	170
20	Reduction	18%						5%						10%						2%			
Dis Cu	Inflow	2.0																					
(ug/L)	Outflow	1.7																					
1.0	Reduction	15%																					
Dis Zn	Inflow	N.D.																					
(ug/L)	Outflow	36																					
20	Reduction	#VALUE!																					

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Aqua-Net (AN-A) - Park-and-Ride Site

Parameter	Date	3/30/94						05/26/94						6/21/94						8/16/94			
	Session	0						1						2						3			
Units	Total Days	0						56						83						140			
MDL	Total Rain	0.00						2.00						3.16						3.35			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	100						110						84						150	140	150	160
(mg/L)	Outflow	98	100	100	98	98	94	113	100	120	120	120		88	91	83	89			143	140	150	140
5.0	Reduction	2%						-3%						-4%						4%			
Turb.	Inflow							220						79						217			
(NTU)	Outflow							213						87						209			
	Reduction							3%						-10%						4%			
Tot P	Inflow	0.18						0.46						0.19									
(mg/L)	Outflow	0.17						0.47	0.45	0.47	0.49			0.19	0.20	0.18	0.20						
0.050	Reduction	6%						-2%						-2%									
O/G	Inflow	34	35	32	32	37		40	21	48	52			24	21	22	28			21	22	18	23
(mg/L)	Outflow	15	16	14	14	14		26	27	38	12			25	23	25	26	28	23	18	15	18	20
1.0	Reduction	57%						36%						-6%						16%			
Hard	Inflow																						
(mg/L)	Outflow	520																					
1.0	Reduction																						
Tot Cu	Inflow	16						21.0						39									
(ug/L)	Outflow	16						15.3	15.0	15.0	16.0			36	34	38	36						
1.0	Reduction	0%						27%						0									
Tot Pb	Inflow	17						26.0						30									
(ug/L)	Outflow	17						20.0	20.0	19.0	21.0			27	29	26	25						
2.0	Reduction	0%						23%						0									
Tot Zn	Inflow	190						220						260	260	260				167	150	190	160
(ug/L)	Outflow	202	240	200	190	190	190	227	230	220	230			253	250	250	260	260		240	260	250	210
20	Reduction	-6%						-3%						3%						-44%			
Dis Cu	Inflow	1.2																					
(ug/L)	Outflow	1.2																					
1.0	Reduction	0%																					
Dis Zn	Inflow	130																					
(ug/L)	Outflow	61																					
20	Reduction	53%																					

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Enviro-Drain (ED-SAA) Park-and-Ride Site

Parameter	Date	3/30/94						05/26/94						6/21/94						8/16/94			
	Session	0						1						2						3			
Units	Total Days	0						56						83						140			
MDL	Total Rain	0.00						2.00						3.16						3.35			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	92						140						98						151	155	150	147
(mg/L)	Outflow	98	93	96	100	93	110	101	110	100	92			84	82	83	86			150	150	149	150
5.0	Reduction	-7%						28%						15%						1%			
Turb.	Inflow							214						85						188			
(NTU)	Outflow	NT						211						89						193			
	Reduction							1%						-5%						-3%			
Tot P	Inflow	0.19						0.49						0.19									
(mg/L)	Outflow	0.18						0.36	0.26	0.38	0.43			0.22	0.21	0.23							
0.050	Reduction	5%						27%						-16%									
O/G	Inflow	59	52	70	62	50		29	28	32	27			44	43	28	60			29	19	45	23
(mg/L)	Outflow	19	16	21	18	19		30	32	28	32	27		46	43	42	47	52	45	18	15	18	20
1.0	Reduction	68%						-3%						-5%						39%			
Hard	Inflow																						
(mg/L)	Outflow	360																					
1.0	Reduction																						
Tot Cu	Inflow	15						20						39									
(ug/L)	Outflow	14						15	15	15	14	14		38	42	39	33						
1.0	Reduction	7%						28%						3%									
Tot Pb	Inflow	17						26						27									
(ug/L)	Outflow	20						17	17	17	16	17		26	28	26	24						
2.0	Reduction	-18%						36%						4%									
Tot Zn	Inflow	180						240						260						210	230	200	200
(ug/L)	Outflow	164	150	160	170	180	160	200	200	200	200	200		267	280	260	260			210	200	230	200
20	Reduction	9%						17%						-3%						0%			
Dis Cu	Inflow	5.6																					
(ug/L)	Outflow	2.3																					
1.0	Reduction	59%																					
Dis Zn	Inflow	61																					
(ug/L)	Outflow	45																					
20	Reduction	26%																					

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Enviro-Drain (ED-A) - Maintenance Shop Site

Parameter		3/30/94						5/25/94						8/18/94			
	Date																
	Session	0						1						2			
Units	Total Days	0						47						133			
MDL	Total Rain	0.00						2.90						4.70			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	91						130						114	63	140	140
(mg/L)	Outflow	100	100	100	100	100	100	120	110	120	130			143	140	150	140
5.0	Reduction	-10%						8%						-25%			
Turb.	inflow	177						203						270			
(NTU)	Outflow	177						211						259			
	Reduction	0%						-4%						4%			
Tot P	Inflow	0.17						0.42									
(mg/L)	Outflow	0.14						0.38	0.38	0.39	0.38						
0.050	Reduction	18%						9%									
O/G	Inflow							28	28	22	35			30	28	32	30
(mg/L)	Outflow							24	25	25	22			48	61	56	27
1.0	Reduction							15%						-60%			
Hard	Inflow																
(mg/L)	Outflow	330															
1.0	Reduction																
Tot Cu	Inflow	17						20									
(ug/L)	Outflow	16						17	17	17	17						
1.0	Reduction	6%						15%									
Tot Pb	Inflow	16						25									
(ug/L)	Outflow	17						22	22	22	22						
2.0	Reduction	-6%						12%									
Tot Zn	Inflow	160						230						230	260	210	220
(ug/L)	Outflow	188	190	180	190	180	200	217	210	220	220			207	210	210	200
20	Reduction	-18%						6%						10%			
Dis Cu	Inflow	1.9															
(ug/L)	Outflow	2.7															
1.0	Reduction	-42%															
Dis Zn	Inflow	45															
(ug/L)	Outflow	30															
20	Reduction	33%															

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Aqua-Net (AN-A) - Maintenance Shop Site

Parameter		3/30/94						5/25/94						8/16/94			
	Date	3/30/94						5/25/94						8/16/94			
	Session	0						1						3			
Units	Total Days	0						47						133			
MDL	Total Rain	0.00						2.90						4.70			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	100						130						147	150	140	150
(mg/L)	Outflow	98.0	100	100	98	98	94	110	120	110	100			137	140	140	130
5.0	Reduction	2%						15%						7%			
Turb.	Inflow	117						189						279			
(NTU)	Outflow	121						188						272			
	Reduction	-3%						1%						3%			
Tot P	Inflow	0.18						0.43	0.44	0.41							
(mg/L)	Outflow	0.17						0.38	0.38	0.35	0.42						
0.050	Reduction	6%						10%									
O/G	Inflow	34	35	32	32	37		18	19	16	19			20	14	25	22
(mg/L)	Outflow	15	16	14	14	14		16	17	16	16			20	19	20	21
1.0	Reduction	57%						9%						2%			
Hard	Inflow																
(mg/L)	Outflow	520															
1.0	Reduction																
Tot Cu	Inflow	16						19	19	19							
(ug/L)	Outflow	16						17	17	17	16						
1.0	Reduction	0%						12%									
Tot Pb	Inflow	17						26.5	26	27							
(ug/L)	Outflow	17						22.0	23	22	21						
2.0	Reduction	0%						17%									
Tot Zn	Inflow	190						235	240	230				197	170	230	190
(ug/L)	Outflow	202	240	200	190	190	190	207	210	210	200			183	200	160	190
20	Reduction	-6%						12%						7%			
Dis Cu	Inflow	1.2															
(ug/L)	Outflow	1.2															
1.0	Reduction	0%															
Dis Zn	Inflow	130															
(ug/L)	Outflow	61															
20	Reduction	53%															

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Aqua-Net (AN-S) - Arterial Site

Parameter	Date	3/30/94						6/16/94						8/18/94	ISSING		
	Session	0						1						2			
Units	Total Days	0						65						118			
MDL	Total Rain	0.00						1.80						2.83			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	99						84						150	150	140	160
(mg/L)	Outflow	94	93	98	98	94	86	76	78	77	73			147	140	150	150
5.0	Reduction	5%						10%						2%			
Turb.	Inflow	145						75						289			
(NTU)	Outflow	149						77						288			
	Reduction	-3%						-3%						0%			
Tot P	Inflow	0.19						0.24									
(mg/L)	Outflow	0.20						0.22	0.22	0.22	0.21						
0.050	Reduction	-5%						10%									
O/G	Inflow							45	48	50	38			17	22	14	14
(mg/L)	Outflow	NT						34	37	41	35	30	28	16	19	15	13
1.0	Reduction							25%						6%			
Hard	Inflow																
(mg/L)	Outflow	840															
1.0	Reduction																
Tot Cu	Inflow	12						21									
(ug/L)	Outflow	11						19	20	18	18						
1.0	Reduction	8%						11%									
Tot Pb	Inflow	17						27									
(ug/L)	Outflow	11						29	29	30	28	25	33				
2.0	Reduction	35%						-7%									
Tot Zn	Inflow	190						270						200	220	180	200
(ug/L)	Outflow	182	200	180	170	180	180	263	270	260	260			237	270	220	220
20	Reduction	4%						2%						-18%			
Dis Cu	Inflow	1.9															
(ug/L)	Outflow	2.0															
1.0	Reduction	-5%															
Dis Zn	Inflow	44															
(ug/L)	Outflow	130															
20	Reduction	-195%															

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Stormwater Services (SS-20) - Arterial Site

Parameter	Date	3/30/94						5/16/94						8/18/94			
Units	Session	0						1						2			
MDL	Total Days	0						65						118			
	Total Rain	0.00						1.80						2.83			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	96						86						143	140	140	150
(mg/L)	Outflow	89	92	91	89	89	84	65	70	69	55			123	120	130	120
5.0	Reduction	7%						25%						14%			
Turb.	Inflow							75						279			
(NTU)	Outflow							77						252			
	Reduction							-3%						10%			
Tot P	Inflow	0.18						0.26									
(mg/L)	Outflow	0.15						0.20	0.21	0.20	0.20						
0.050	Reduction	17%						22%									
O/G	Inflow	36	37	37	37	34		35	35	37	34			32	28	35	32
(mg/L)	Outflow	4.5	4.6	4.4	4.6	4.4		26	23	33	22	23	28	16	18	15	16
1.0	Reduction	88%						27%						48%			
Hard	Inflow																
(mg/L)	Outflow	450															
1.0	Reduction																
Tot Cu	Inflow	14						20									
(ug/L)	Outflow	13						22	19	20	28	20	22				
1.0	Reduction	7%						-9%									
Tot Pb	Inflow	18						28									
(ug/L)	Outflow	13						31	28	30	34						
2.0	Reduction	28%						-10%									
Tot Zn	Inflow	200						240						220	210	250	200
(ug/L)	Outflow	164	160	160	150	170	180	277	280	270	280			240	280	210	230
20	Reduction	18%						-15%						-9%			
Dis Cu	Inflow	2.0															
(ug/L)	Outflow	1.7															
1.0	Reduction	15%															
Dis Zn	Inflow	N.D.															
(ug/L)	Outflow	36															
20	Reduction																

NT = Not tested.
ND = Not Detected

First Sequence Test Data (continued)

Enviro-Drain (ED-SAA) Arterial Site

Parameter	Date							6/16/94						8/18/94			
Units	Session	0						1						2			
MDL	Total Days	0						65						118			
	Total Rain	0.00						1.80						2.83			
		Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3	Rep4	Rep5	Average	Rep1	Rep2	Rep3
TSS	Inflow	92						78						140	140	140	140
(mg/L)	Outflow	98	93	96	100	93	110	64	63	59	65	69	63	153	150	150	160
5.0	Reduction	-7%						18%						-10%			
Turb.	Inflow	166						75						284			
(NTU)	Outflow	163						79						271			
	Reduction	2%						-5%						5%			
Tot P	Inflow	0.19						0.21									
(mg/L)	Outflow	0.18						0.22	0.21	0.22	0.24						
0.050	Reduction	5%						-6%									
O/G	Inflow	59	52	70	62	50		48	50	38				14	15	13	15
(mg/L)	Outflow	19	16	21	18	19		34	37	41	35	30	28	27	30	23	28
1.0	Reduction	68%						29%						-88%			
Hard	Inflow																
(mg/L)	Outflow	360															
1.0	Reduction																
Tot Cu	Inflow	15						19									
(ug/L)	Outflow	14						18	19	16	19						
1.0	Reduction	7%						5%									
Tot Pb	Inflow	17						27									
(ug/L)	Outflow	20						32	35	24	38						
2.0	Reduction	-18%						-20%									
Tot Zn	Inflow	180						290						167	180	160	160
(ug/L)	Outflow	164	150	160	170	180	160	270	280	260	270			187	180	190	190
20	Reduction	9%						7%						-12%			
Dis Cu	Inflow	5.6															
(ug/L)	Outflow	2.3															
1.0	Reduction	59%															
Dis Zn	Inflow	61															
(ug/L)	Outflow	45															
20	Reduction	26%															

NT = Not tested.
ND = Not Detected

Appendix C: Companion Study by the Port of Seattle

Study objective: The objective of the study was to determine if a catch basin insert will improve the performance of a catch basin. The approach was to compare the amount of sediment removed by sumps without the overlying insert to catch basins with an insert.

Test site: The test site is a 10 acre area, recently developed. The site is used for the storage of containers. Inserts (Stormwater Services, Type 1) were placed in nine catch basins; nine additional catch basins were used as control sites. The sump dimensions are 20" by 24"; the depth of the sumps ranged from 3.5 to 5 feet below the invert of the outlet.

Test procedure: The sumps were cleaned and the inserts were installed on February 4, 1994 to begin the experiment. The sumps and inserts were cleaned again on July 8, 1994 to end the experiment. Sediment removed from the sumps with inserts, including the sediment in the inserts, was kept separate from the sediment removed from the sumps without inserts. The removed sediment was air dried and weighed.

The inserts were periodically observed to ascertain if accumulation-washout was occurring in the inserts. The observations suggest that accumulation-washout was not occurring as the depth of the sediment gradually increased through the period of the experiment.

Results: The amount of sediment removed by the inserts was 200 pounds; the sediment removed by the underlying sumps was 270 pounds. Therefore, a total of 470 pounds was removed by the catch basins with inserts or about 47 pounds by each catch basin. The sumps in the seven catch basins without inserts removed about 330 pounds or 47 pounds per catch basin sump.

A size distribution analysis was done of sediment from the inserts and the sumps. The data shown below indicate no difference in the size distribution. Most of the captured sediment was sand.

Size Fraction	Insert Sediment	Sump Sediment
Gravel	18.1	19.0
Sand	66.0	66.1
Silt	6.4	6.0
Clay	9.5	8.9

Conclusion: The experiment found that a catch basin in combination with an insert performed no more effectively than just the sump.

There is some question as to the applicability of these results to other sites. Midway during the experiment it was discovered that the test site was unique with two respects. First, portions of the site are unpaved. The site has designated areas for the containers; these areas are composed of a designed gravel mix. The lanes between the designated

storage areas through which the containers are moved are paved. It was noticed that during rainy periods when the container-movers (call top-picks) move off the paved area, the wheels "pump" sediment to the surface which is then washed onto the pavement and into the catch basins. In addition, the paved areas are washed daily during dry periods to prevent fugitive dust emissions. The site is therefore unusual with regard to the amount sediment washed from a developed site and the presence of pavement washing.

It is also noted that the sumps present at this site meet the criteria that USEPA (1977) has found necessary to effectively remove sediments; the USEPA recommends that both the width and depth of the sump be at least four times the diameter of the outlet pipe. Sumps at the Port site meet these criteria. However, where the sump is much smaller and does not meet the recommended criteria an insert may improve the overall performance. The inserts in this study did remove a significant amount of sediment.

Observations on the removal mechanisms: The volume of the sumps range from 10 to 20 cubic feet whereas the inserts units have a volume of only about one cubic feet. Despite their relatively small volume the inserts represented about 43% of the performance. That the inserts played such a significant role suggests that the majority of removal occurs during the wash-off period, rather than between wash-off periods. If so, removal is a function of insert (or sump) surface area (overflow rate) rather than insert (or sump) volume. The surface area of each tray is essentially the same surface area as the sumps (about 2 versus about 3.3 ft2, respectively); therefore, whatever the sumps are capable of capturing the trays can also remove; and conversely, whatever is removed by the trays is not available to be removed by the sumps. This is perhaps reasonable since wash-down occurs several times each day and therefore there is little time for settling to occur between wash-down events. That removal occurs primarily during wash-off is suggested by the size distribution analysis: 75% of the captured material is sand and gravel.

Other observations:

1. Clogging of the filter fabric occurred quickly, within a few days of replacement.
2. Accumulation appeared to gradually build over the four month period. There did not appear to be a cycle of accumulation and washout.
3. However, washout does appear to occur around the edges and the outlet of the upper tray. The accumulation is much deeper in the center of the upper tray.
4. Little accumulation occurred in the lower tray, even though by May 25th it seemed that the upper tray in many of the units was "full".
5. It seems that for this site the units need to cleaned only twice yearly, and only the upper tray. The lower tray need only be cleaned once yearly or once every two years.
6. The units were easily serviced: just remove the trays and "tap" the material into a garbage can; and replace the fabric. Total time of about five minutes per unit. One person is quite capable of doing the maintenance.
7. The units are not "water-tight". Leakage occurs between the catch basin rim and the adapter.